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ABSTRACT

This document reports the state of science achievement of Japanese students based on the Second International Science study conducted in 1983-84. Results are compared to the first study conducted in 1970. The target populations, samples, and structure of the second study are described. Test results including score distribution and high and low response rates were provided for elementary, lower secondary and upper secondary students. Significant correlations were reported between the correct response rates and subject areas studied. There was no sex difference at the elementary level, but at the middle school level sex differences were reported. A table comparing populations on some common questions for high school students is provided. At the elementary level there was no difference between the results this time and in 1970, however the scores of middle school students improved. Some of the problems that were better or worse than the 1970 assessment are considered. Results on process tests, factors related to science achievement, and sex differences in attitudes towards science are reported. (YP)

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SCIENCE ACHIEVEMENT OF ELEMENTARY AND SECONDARY SCHOOL STUDENTS IN JAPAN: THE RESULTS OF THE IEA STUDY

Section for International Co-operation in Education
NATIONAL INSTITUTE FOR EDUCATIONAL RESEARCH OF JAPAN

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Section for International Co-operation in Education
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NOTE

This paper was prepared originally in Japanese by Mr. Masao Miyake, Chief, Section for Science Education, Research Centre for Science Education, National Institute for Educational Research (NIER), for translation into English for dissemination under the NIER's Information Services Programme among the Unesco Member States in Asia and the Pacific.

1. Introduction

Following the First International Science Study (FISS) in 1970, the International Association for the Evaluation of Educational Achievement (IEA) conducted the Second International Science Study (SISS) in 1983-84.

The number of countries taking part in SISS increased to 23 compared to 19 who participated in FISS.

In Japan, an internal country report was issued in October 1985. On the basis of the report, the aims of this paper are to outline the state of science achievement of Japanese students and to compare it with the position in 1970. As far as international comparisons are concerned, the international centre for SISS is expected to publish its findings following to their analysis, in the course of 1988-89.

The aims of SISS may be summed up as follows:

1) To investigate, by means of large-scale survey methods, the state of science education throughout the world;

2) To investigate how science education has changed since the early 1970s;

3) To elucidate factors which can explain different results of science achievements between countries and between students within a country; and

4) To elucidate differences from the situation in the early 1970s in respect of patterns connecting levels of science achievements and their causative factors.

In the case of Japan, the aim for participating in the study has been to identify the science achievements as well as other special characteristics of students and to provide data for the improvement of science education in the future.

2. Target Populations and Sampling

On the basis of the international definitions prepared by SISS, survey populations in Japan were defined as follows:

Population 1: All students in the 5th year of elementary school.

Population 2: All students in the 3rd year of lower secondary school.

Population 3/3N: All 3rd year upper secondary school students attending full-time general or mathematics/ science courses.

Sub-population groups were also defined as follows:

3P: All students who have completed Physics II (Advanced Course) by the end of the 3rd year;
3C: All students who have completed Chemistry II;
3B: All students who have completed Biology II;
3E: All students who have completed Earth Science II; and
3N(non-science): All students other than those included in 3P, 3C, 3B or 3E.

With regard to the extraction of samples, populations 1 and 2 were each set at 200 schools and 8,000 students, with stratified sampling by kind of school, size of school and size of local population. In the case of population 3/3N, the sample size was set at approximately 200 schools and 7,200 students, and stratified sampling was carried out by subject. The sample data are shown in Table 1.

Table 1: The Samples

Populations	No. of Students	No. of Teachers	No. of Schools
Elementary (5th year)	7,925	545	221
Lower Secondary (3rd year)	7,610	314	199
Upper Secondary (3rd year)	6,561	133	193
physics	1,187	36	36
chemistry	1,468	43	43
biology	1,212	38	38
earth science	464	16	16
non-science	2,230	0	60
Total	22,096	992	613

3. The Contents and Structure of the Surveys

As in the case of FISS, so too with SISS, various kinds of surveys were carried out in respect of countries, schools, teachers and students. At the country level, there was a National Science Curriculum Case Study, which surveyed science content, etc. in respect of target populations as well as the education system of the country concerned. This corresponds to the National Case Study of the FISS, and was designed to identify changes in the science education of the country for a period of more than 10 years following the first survey and to act as a base for the formulation of subsequent questions.

As far as the main survey is concerned, items consist of school questionnaire, teacher questionnaire, students questionnaire, science problems, surveys of opportunity to learn, calculation problems, and practical tests for laboratory works. In view of the fact that 3 to 4 hours was seen as the realistic limit for a survey of students, it was recognized that it might be impossible for some items to be completed, depending on the state of affairs in the country concerned. So in addition to International Core Components, there are International Options which a country is free to implement or not, and National Options which a country may include some additional question items. It has been decided to include International Options in the international report, but not National Options. The practical tests for laboratory works as a whole constitute an International Option, and after all only a number of countries, including Japan would implement these.

I) The Structure of Science Problems

Since one aim of SISS was to compare the results with the results of the FISS, it was necessary to include a number of problems which were the same as those set in the FISS. In the light of this considerations among others, the science problems for each population were determined.

There are various slight differences resulting from the target populations, but in terms of the subject areas covered, these are divided into physics, chemistry, biology and earth science, and in terms of objectives, these are divided into knowledge, understanding and application. Also, in the case of sub-population 3N (non-science), the area of health and hygiene has been added. For the practical test questions for laboratory works, separate objective classifications have been assigned.

The objective classifications for the science problems are the same as in the case of FISS; details of the contents are as follows:

Knowledge

This implies basic knowledge and skill, but great weight is not placed simply on knowledge of isolated facts. Real ability to acquire scientific information is included.

Understanding

This implies ability to use the knowledge gained through a familiar situation such as the classroom, science laboratory or textbook.

Application

This combines the contents of 'application' as understood at the time of the FISS (the ability to extract and apply appropriate knowledge in a new situation) with 'higher process' contents (the bringing together of a wide range of

concepts including analysis, synthesis and evaluation, as well as problem-solving).

In terms of science problems, there are problems which were given to all the samples (common problems) and problems which were given to only some samples (optional problems).

For the elementary 5th year population and the lower secondary 3rd year population, the optional problems were divided into four kinds, A to D, and the students surveyed were given 2 kinds of problems selected at random from the available four. In the case of these two populations therefore, all students were given the common problems and each received half the possible optional problems. This system of assigning optional problems is called rotation, and the special characteristic of rotation is that it enables information to be obtained about a larger number of problems with a saving in time, but on the other hand, one still has the trouble of having to statistically process such things as the definition of the total points gained, etc. In the case of an international comparative study such as the present survey, there can be a wide difference in science contents from country to country, and rotation has been adopted while bearing this point in mind.

In the case of the upper secondary 3rd year population, common problems were given to population 3 (including the sub-population groups of physics, chemistry, biology and earth science) and to population 3N (non-science); and optional problems (divided by subject area) were given to the appropriate sub-population groups.

The structure of the science problems for each population is given in Tables 2 to 4.

Table 2: The Structure of Science Problems for the 5th Year Elementary School

Common problems (1M): 24 problems. Time limit : 40 mins.

Objectives / Area	Knowledge	Understanding	Application	Total
Physics	1	4	3	8
Chemistry	1	0	1	2
Biology	1	3	4	8
Earth Science	2	1	3	6
Total	5	8	11	24

Optional problems (1A to 1D): Problems (16 in all) to be taken from any two of the 4 groups (8 from each group). Time limit: 30 mins.

Group	Area / Objectives	Physics	Chemistry	Biology	Earth Science
1A	Knowledge	1	2	1	0
	Understanding	0	0	0	1
	Application	0	2	0	1
1B	Knowledge	0	1	3	1
	Understanding	2	0	0	0
	Application	1	0	0	0
1C	Knowledge	0	0	3	0
	Understanding	3	0	0	1
	Application	1	0	0	0
1D	Knowledge	0	0	3	0
	Understanding	1	0	2	0
	Application	2	0	0	0

Table 3: The Structure of Science Problems for the 3rd Year Lower Secondary School

Common problems (2M): 30 problems. Time limit: 40 mins.

Area / Objectives	Knowledge	Understanding	Application	Total
Physics	1	3	6	10
Chemistry	2	2	0	4
Biology	2	2	6	10
Earth Science	2	0	4	6
Total	7	7	16	30

Optional problems (2A to 2D): Problems (29 in all) to be taken from any two of the 4 groups (19 from each group). Time limit: 30 mins.

Group	Area / Objectives	Physics	Chemistry	Biology	Earth Science
2A	Knowledge	0	1	0	0
	Understanding	3	0	1	0
	Application	1	2	2	0
2B	Knowledge	1	1	2	0
	Understanding	5	1	0	0
	Application	0	0	0	0
2C	Knowledge	2	0	1	0
	Understanding	0	2	0	0
	Application	0	1	3	1
2D	Knowledge	0	0	4	0
	Understanding	1	2	0	2
	Application	0	1	0	0

Table 4: The Structure of Science Problems for the 3rd Year Upper Secondary School

Common problems (3M): 30 problems. Time limit: 40 mins.

Area / Objectives	Knowledge	Understanding	Application	Total
Physics	0	4	4	8
Chemistry	1	4	4	9
Biology	2	3	4	9
Earth Science	0	1	3	4
Total	3	12	15	30

Optional problems (3P, 3C, 3D, 3E): 30 problems to be given to each population. Time limit: 40 mins.

Objectives \ Population	Physics (3P)	Chemistry (3C)	Biology (3B)	Earth Science (3E)
Knowledge	9	8	11	8
Understanding	16	12	13	14
Application	5	10	6	8
Total	30	30	30	30

Optional problems (3N)for non-science students: 30 problems. Time limit: 40 mins.

Area \ Objectives	Knowledge	Understanding	Application	Total
Physics	1	2	5	8
Chemistry	4	0	2	6
Biology	1	6	1	8
Earth Science	0	3	1	4
Others	4	0	0	4
Total	10	11	9	30

2) The Composition of Questionnaires

As already explained with reference to objectives, the purpose of this survey is not simply to compare high marks and low marks in respect of science problems. The main purpose is rather to identify what factors influence the results and to analyze statistically the influence each of them has. Accordingly, a very wide range of question items which might be connected with the results was included in the survey questionnaires.

The National Science Curriculum Case Study covered fixed items such as education system (e.i. 6-3-3) or the school-entering ages, etc. and these were reported to the international headquarters along with the curriculum survey. On the other hand, factors which varied according to school and teacher, or factors concerned with the attitude and way of thinking of the student were surveyed by means of school, teacher and student

questionnaires.

1) School questionnaire (survey of opportunity to learn)

The school questionnaire include, basic characteristics of the school, questions on the type of locality (as indicators of urbanization), the total number of teaching hours, number of students and number of teachers. In addition items specific to a school such as PTA activities, the style of science teaching, the purchase and introduction of science apparatus, etc. were also included.

Also surveyed, in respect of each science problems was the extent to which students in a given school year had learned the material, in other words, the survey of opportunity to learn.

2) Teacher questionnaire

In addition to objective questions in respect of each teacher such as sex, age, experience, number of teaching hours, etc. the questionnaire also include items showing the teacher's eagerness, such as the time spent in lesson preparation, reading of specialist books, style of teaching, use of different kinds of teaching materials, etc. as well as items having a particularly close connection with science, such as outdoor teaching, use of experimental apparatus, etc.

3) Student questionnaire

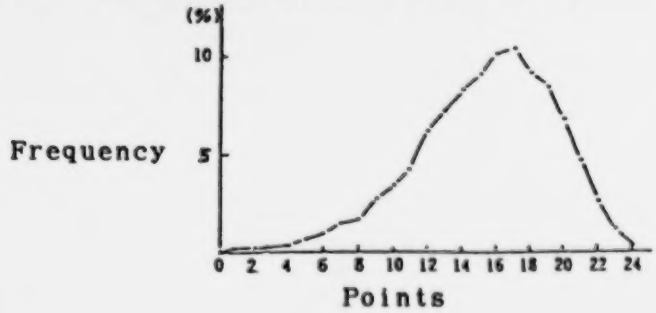
Student questionnaire can be broadly divided into two parts: one for questions on a student and his/her individual background, such as age, sex, number of brothers and sisters, number of books owned by the family, etc; and the other for questions concerned with a student's opinions or attitudes, such as self-evaluation of results, likes or dislikes among subjects, value assessment of science, interest in science, etc.

4. Science Test Results

5th Year Elementary School Population

1) Figure 1 shows the distribution of points gained on the basis of 1 point for each of 24 common questions (i.e. 24 points indicates full marks). With an average number of points gained of 15.4 (63,3%), the standard deviation is 4.0 points (16.5%). The number of points gained by the largest number of students was 17 (70.8%).

Figure 1: Points Distribution for Common Questions (5th Year Elementary School Population)



Sample size : 7,925 Maximum number of points : 24
Average : 15.43 Standard deviation : 3.97

2) In respect of the total of 56 questions, including both common questions and optional questions, Table 5 and 6 show the questions where correct answers were relatively high compared to the average (85% and over) and the questions where correct answers were relatively low (less than 45%). 11 questions produced correct responses of 85% and more, while 10 produced correct responses of less than 45%. In the case of almost all questions, the correct response rate was more than 50%. In the case of most of the questions with a high correct response rate, there was a diagram in the question or in the multiple-choice answers.

Table 5: Questions with a Comparatively High Response Rate (85% and over) - 5th Year Elementary School Population

Question Number	Area Objectives	Correct Response Rate (Percentage of Opportunity to learn)	Contents of Question
Common			
M3	Earth Science	89.6%	Show diagrams the shadow of a tree, the same point, observed at five difference times and ask children to choose the diagram corresponding to 12.00 mid-day.
	Understanding	66.1%	
M4	Earth Science	89.4%	Show in a table the results of temperature readings taken over a 12.00 hours and ask children to select the time during the three days when the temperature was highest.
	Application	84.2%	

Common			
M24	Physics	91.3%	Show three diagrams of 2 torch batteries connected up in different ways and ask children to choose which one will make the bulb light up.
	Understanding	95.0%	
Optional			
A4	Biology	91.7%	Show a butterfly egg, caterpillar, chrysalis and mature butterfly in irregular order and ask children to arrange them in the correct order of development.
	Knowledge	95.0%	
B1	Physics	87.1%	Show by diagrams a balloon placed over the neck of a bottle expanding as the bottle is heated and ask children to identify the reason why the balloon is expanding.
	Application	85.5%	
B5	Biology	91.7%	Show pictures of a grasshopper, a butterfly, a bat, a praying mantis and a frog, and ask the children to choose which is the parent of a caterpillar.
	Knowledge	91.4%	
C1	Biology	93.6%	Ask children to choose from a hen, a dog, a frog and a turtle which does not lay eggs.
	Knowledge	60.6%	
C4	Biology	97.2%	Show frog spawn, a tadpole, a tadpole that has developed legs and a mature frog in irregular order and ask children to arrange them in the correct order of development.
	Knowledge	65.6%	
C5	Physics	87.4%	In diagrams of a circuit connecting a battery to a bulb, show in the circuit, a break, a nail, a 10-yen coin and an eraser, and ask the children to choose the circuit which will enable the bulb to light up.
	Application	85.5%	
C7	Physics	88.9%	Show pictures of a magnet being pulled out of mounds of 3 different substances and ask children to choose which one might be thought to be sugar.
	Understanding	95.5%	
D1	Biology	97.8%	Show pictures in an irregular order of a bean seed, a seedling, a young plant and a mature bean plant, and ask the children to arrange them in the correct order of development.
	Knowledge	54.3%	

Table 6: Questions with a Comparatively Low Response Rate (less than 45%) - 5th Year Elementary School Population

Question Number	Area Objectives	Correct Response Rate Percentage of Opportunity to learn	Contents of Question
Common			
M22	Physics	33.7%	If the same amount of water and paraffin oil are put into 2 glasses, which are put to stand by the window on a fine day, after 2 or 3 hours have passed, the oil will have decreased substantially. Ask the children what it is intended to investigate through this experiment.
	Application	28.5%	
Optional			
A3	Biology	23.9%	Given a small rabbit which cannot walk well because it has hurt a leg, ask the children to choose whether a) it cannot walk well, b) it can walk well, or c) only part of it cannot walk well.
	Application	6.3%	
A5	Chemistry	43.2%	Ask the children to choose from sand, table salt, soap, sugar and air, which substance(s) will not dissolve in water.
	Knowledge	77.8%	
A7	Physics	18.8%	Ask the children to identify the reason why a rubber ball falls back to earth after it is thrown up into the air.
	Knowledge	11.3%	
B4	Earth Science	24.2%	Ask children to say whether the sun is a planet, a fixed star, a comet or a meteorite.
	Knowledge	10.0%	
B8	Chemistry	41.2%	Ask children to identify from which of a) a dead tree, b) water, c) animal bones, d) rock, or e) paraffin oil, minerals such as aluminum and iron are extracted.
	Knowledge	4.1%	
C3	Biology	34.0%	Ask children to choose from 5 options why lungs are necessary to man.
	Knowledge	6.3%	

Optional			
C8	Physics	44.5%	Ask children to choose from 5 diagrams the one corresponding to the mirror image of 'FUN', i.e. the way 'FUN' would appear in a mirror.
	Understanding	41.2%	
D4	Physics	21.4%	Ask children to choose from 5 diagrams the easiest method of moving a large stone by using a lever.
	Understanding	8.6%	
D7	Biology	38.7%	Ask children to identify from where a fish mainly gets the air that it needs to live.
	Knowledge	20.4%	

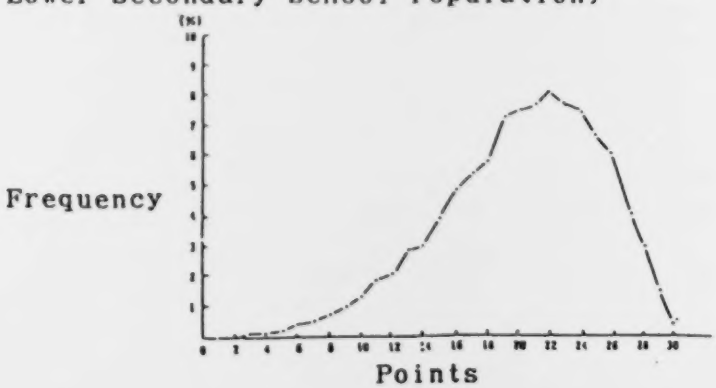
3) In the case of all questions including common and optional, there is a significant correlation of a 5% significant level between correct responses and subject areas studied, so that correct responses are high when the subject area has been covered.

4) In the case of common questions, the average correct response level for boys (standard deviation is given in brackets) was 64.8% (16.9%), and for girls 63.8% (16.1%), showing no statistically significant difference between the sexes.

3rd Year Lower Secondary School Population

1) Figure 2 shows the distribution of points in respect of 30 common questions on the basis of 1 point for each question (i.e. 30 points equals full marks). With an average number of points gained of 20.2 (67.4%), the standard deviation is 5.0 points (16.8%). The number of points gained by the largest number of students was 22 (73,3%).

Figure 2: Distribution of Points for Common Questions (3rd Year Lower Secondary School Population)



Sample size : 7,610 Maximum number of points : 30
Average : 20.22 Standard deviation : 5.03

2) In respect of a total of 70 questions including common and optional questions, Table 7 and 8 respectively show questions where the response rate was comparatively high (85% and over) and questions where the response rate was comparatively low (less than 50%). 14 questions produce a correct response rate of 85% or more, and 10 questions produce a correct response rate of less than 50%.

Table 7: Questions with a Relatively High Correct Response Rate (85% and over) - 3rd Year Lower Secondary School Population.

Question Number	Area Objectives	Correct Response Rate (Percentage of Opportunity to learn)	Contents of Question
Common			
M4	Earth Science	88.7%	Get children to choose from pictures of a number of thermometers one which corresponds to one of the temperatures shown on a list.
	Application	97.5%	
M5	Earth Science	87.1%	From a diagram showing temperatures taken at different times of day get children to deduce when a cold wind began to blow.
	Application	88.4%	
M21	Physics	97.4%	Get children to measure the length of a piece of wood from a scale shown in the diagram.
	Understanding	94.5%	
M22	Physics	89.0%	Get children to choose one from a number of experiments to measure the extent to which rubber balls bounce.
	Application	54.3%	
M28	Physics	95.0%	From diagrams showing a number of ways of connecting 2 batteries to a bulb, get children to choose all those which enable the bulb to light up.
	Understanding	96.0%	
M30	Physics	86.2%	From a number of diagrams showing three bulbs connected in a circuit with a battery and a switch, get children to choose the circuit where one specified bulb will light up when the switch is switched off.
	Application	92.5%	
Optional			
A1	Biology	86.9%	Get children to choose an experimental method (with control experiment) to investigate the conditions for germination of a plant.
	Application	60.8%	

Optional			
A4	Physics	93.6%	Get children to choose the reason why, after air has been pumped into a bicycle tire, it gradually becomes difficult to pump in more air.
	Understanding	83.9%	
A5	Chemistry	89.2%	When 3 candles are lit under conditions of varying amounts of air, get children to choose the order in which the flame will be extinguished.
	Application	89.9%	
A7	Physics	86.5%	From diagrams showing 2 people of different weights on a see-saw, get children to choose the one where the see-saw will balance.
	Understanding	69.3%	
B4	Physics	94.3%	Get children to measure the amount of water in a container by using the measuring cylinder in the water.
	Understanding	99.0%	
B7	Physics	85.5%	From days having varying conditions of temperature, humidity and wind, get children to choose the day when water will evaporate fastest.
	Knowledge	90.5%	
B8	Physics	85.7%	Get children to choose the advantages of using a lever.
	Understanding	90.5%	
C5	Physics	87.5%	Get children to choose the diagram which correctly shows the way light passes through a convex lens.
	Knowledge	32.7%	

Table 8: Questions with a Relatively Low Correct Response Rate (less than 50%) - 3rd Year Lower Secondary School Population

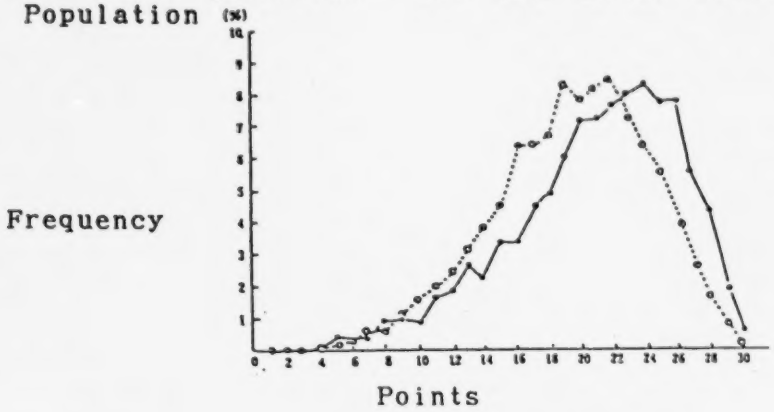
Question Number	Area Objectives	Correct Response Rate: Percentage of Opportunity to learn	Contents of Question
Common			
M11	Biology	47.6%	Get children to choose human nerve cells from pictures showing 5 kinds of cells.
	Knowledge	87.9%	
M20	Chemistry	20.4%	From the particles making up an atom, get children to choose the one that causes sharing or covalence at the time of chemical change.
	Knowledge	14.6%	
M23	Physics	48.7%	Get children to choose the answer which shows what will happen when the mass of 2 gas cylinders, one containing a vacuum and the other containing hydrogen, are compared.
	Understanding	89.9%	
M27	Physics	43.2%	Get children to choose what has been investigated when comparing the evaporation of water and paraffin oil under identical conditions.
	Application	55.8%	
Optional			
A3	Biology	45.6%	Get children to choose the reason why meat which has been cooked should not be warmed up again and served to quests the next day.
	Application	41.7%	
A6	Chemistry	26.9%	Get children to choose the correct response from a comparison of the freezing and boiling points of salt water and water.
	Knowledge	57.8%	
B3	Chemistry	21.4%	From the chemical notation of acetic acid get children to identify how many atoms make up one molecule.
	Understanding	69.3%	
B9	Physics	30.6%	Get children to choose a reason why some substances feel colder than others although at the same temperature.
	Understanding	34.2%	
D7	Biology	31.2%	Get children to choose the food that contains the greatest amount of protein.
	Knowledge	49.7%	

Optional			
D10	Biology Knowledge	45.3% 56.3%	Get children to choose the reason why green plants are important to animals.

3) In the case of all questions including common and optional, there is a significant correlation of a statistically significant level of 5% between the correct response rate and subject areas studied. In other words, in subject areas completely studied, the correct response rate is high.

4) Figure 3 shows the points distribution between boys and girls in respect of common questions. The average points score of boys is 21.0 (standard deviation of 5.1 points), and of girls 19.5 points (standard deviation of 4.8 points).

Figure 3: Points Distribution between Boys and Girls in Respect of Common Questions - 3rd Year Lower Secondary School Population



	Male ——o	Female o----o
Sample size :	3,927	3,683
Average :	20.95	19.45
Standard deviation :	5.13	4.79

Comparing the average scores of boys and girls, there is a statistically significant difference of 1% level, with boys higher.

5) Examining differences between the sexes regarding each of all questions, one finds 32 out of the total 70 questions, or nearly half, show a difference of 5% or more between boys and girls. In the case of all these questions, the correct response rate for boys is higher than for girls.

3rd Year Upper Secondary School Population

The 3rd year upper secondary school population is divided into 5 populations for physics, chemistry, biology, earth science

and non-science, but as the same common questions are used with each population, it is possible to compare the points gained in respect of these. Table 9 shows the average correct response percentage (%) and the standard deviation in respect of the common questions.

Table 9: A Comparison between Populations in Respect of Common Questions - 3rd Year Upper Secondary School Population

Subject	Population	Physics	Chemistry	Biology	Earth Science	Non-Science
Common Question	Average Correct Response Level	81.0%	79.9%	65.0%	62.0%	59.9%
	Standard Deviation	14.3%	16.6%	18.5%	15.8%	19.4%
Physics	Average Correct Response Level	83.3%	80.9%	60.0%	59.6%	56.3%
	Standard Deviation	19.8%	22.0%	24.8%	22.3%	24.9%
Chemistry	Average Correct Response Level	77.4%	77.2%	58.6%	53.9%	54.4%
	Standard Deviation	18.3%	20.1%	22.8%	19.4%	23.0%
Biology	Average Correct Response Level	77.3%	76.6%	68.3%	62.3%	59.9%
	Standard Deviation	18.0%	19.8%	22.4%	21.0%	23.4%
Earth Science	Average Correct Response Level	93.0%	91.8%	82.3%	84.5%	77.8%
	Standard Deviation	14.8%	16.8%	22.8%	19.5%	23.8%
Knowledge	Average Correct Response Level	80.0%	78.0%	64.0%	58.3%	55.3%
	Standard Deviation	26.3%	27.3%	31.7%	30.7%	33.0%
Understanding	Average Correct Response Level	81.4%	80.3%	63.8%	60.0%	57.5%
	Standard Deviation	16.4%	19.2%	22.1%	22.1%	23.2%
Application	Average Correct Response Level	80.9%	80.0%	66.3%	64.4%	62.7%
	Standard Deviation	14.9%	16.7%	18.7%	15.9%	19.3%

Taking the above 5 populations, the order of the average correct response rate, starting from the highest is: physics, chemistry, biology, earth science, non-science, but there is a wide gap between physics and chemistry on the one hand and biology, earth science and non-science on the other. Among 3rd year upper secondary school students, it is usual for those intending to go on to study science to complete the advanced courses, Physics II and Chemistry II. So one may assume that among the physics and chemistry populations, there will be many who intend to go on to study science. In the other populations, however, one can deduce that there are a seizable number who will have completed Biology II or Earth Science II in preparation for a nation-wide Joint Achievement Test conducted as the first-stage selection process for entrants to Public Universities or for private university entrance examinations, after which they will study a variety of subjects. It may be assumed that the differences in average points result from this. Population 3/3N, in particular, biology and non-science groups are also seen in populations with a large internal ability distribution range (standard deviation).

Problems Common to Different Populations

In order to look at progress between the 5th year elementary school population and 3rd year lower secondary school population, and between the 3rd year lower secondary school and the 3rd year upper secondary school population, 20 of the same problems (hereafter referred to as 'joint problems') were given to 5th year elementary school and 3rd year lower secondary school populations. 16 joint problems were also given to 3rd year lower secondary school and 3rd year upper secondary school populations.

Table 10 and 11 show the averages in respect of joint problems between the populations in each of the two above groups.

Table 10: A Comparison of Joint Problems as between 5th Year Elementary School and 3rd Year Lower Secondary School Populations

	5th Year Elementary School	3rd Year Lower Secondary School
Average Correct Response Level	61.1%	77.7%
Standard Deviation	13.9%	14.4%

Table 11: A Comparison of Joint Problems as between 3rd Year Lower Secondary School and 3rd Year Upper Secondary School Populations

	3rd Year Lower Secondary School	3rd Year Upper Secondary School				
		Physics	Chemistry	Biology	Earth Science	Non-Science
Average Correct Response Level	60.8%	86.8%	85.3%	71.6%	69.3%	66.6%
Standard Deviation	15.5%	7.7%	7.9%	13.9%	16.6%	14.2%

The average difference between 5th year elementary school and 3rd year lower secondary school is 16.6% with lower secondary school higher; between the 3rd year lower secondary school population and the five sub-populations making up the 3rd year upper secondary population the average difference ranges from 26.0% to 5.8%, but in every case the upper secondary school score is higher.

Comparison with the Previous Survey

The populations that can be compared are those of 5th year elementary school students and 3rd year lower secondary school students, and the dates of the surveys are May 1970 for FISS and May 1983 for SISS. Also, at the time of FISS, 3rd year upper secondary school students were not surveyed in Japan, so no comparison is possible in respect of this population.

Problems common to FISS and SISS (bridge items) number 25 in the case of 5th year elementary school students and 33 in the case of 3rd year lower secondary school students.

Table 12 shows results for elementary school students for FISS and SISS in respect of subject areas, objectives and total average correct response rates.

Table 12: A Comparison between the Present and Previous Survey - 5th year Elementary School Population

Subject area/ Objectives	Number of questions	Average correct response rate		
		Present survey (a) 1983	Previous survey (b) 1970	Difference (a - b)
Physics	9	63.3%	62.6%	0.7%
Chemistry	2	55.5%	59.3%	-3.8%
Biology	8	63.3%	63.9%	-0.6%
Earth Science	6	70.3%	71.9%	-1.6%
Knowledge	6	49.1%	53.5%	-4.4%
Understanding	7	72.3%	75.2%	-2.9%
Application	12	67.4%	64.8%	2.6%
Total	25	64.4	65.0%	-0.6%

In the case of elementary school students, looking from the standpoint of average correct response rates, one could say that there is no difference between the results this time (SISS) and the previous time (FISS). Looking by separate subject area, chemistry stands out as showing lower correct response rates this time, but it is conceivable that this is because the number of questions is less.

Looking in terms of objectives, 'knowledge' and 'understanding' show lower average correct response rates this time, whereas 'application' shows higher rates than the previous FISS. Comparing correct response rates between this survey and the previous one in respect of individual questions, one finds that out of a total of 25 questions, there are 11 where the correct response rates this time are, statistically speaking, significantly higher, and 6 where the correct response rates this time are significantly lower. In all cases where the rate on the previous FISS is recognized as being higher, the difference is 5% or greater, and there are cases, as in the area 'earth science', where the difference is nearly 30%. On the other hand, in the cases where the rate this SISS is higher, in a large number of cases the difference is less than 5%. In passing, without thinking in terms of statistically significant differences, if one simply compares the problems where the differences between the correct response rate on this SISS and the previous FISS is greater than 5%, there are 6 problems where the rate is higher on this SISS and 6 problems where it is lower. The average correct response rate overall is 64.4% on this SISS, compared to 65% on the previous FISS. One could therefore say, in respect of

elementary school students, that there is no difference between their marks in science on this SISS and on the previous FISS.

Let us now look at 2 examples, where the results on this SISS are better than those on the previous FISS.

[Example 1] Area: Physics, Objectives: Application

Yoshiko-san and Michiko-san each bought the same kind of rubber ball. "My ball bounces better than yours," Yoshiko-san said. "Let's test them and see if that's really true," Michiko-san answered.

Among the following methods of investigation, which is the best?

1) Drop the two rubber balls from the same height and measure which bounces the higher.

2) Bounce the two balls off a wall and measure which rebounds further away.

3) Drop the two rubber balls from different heights and measure which bounces the higher.

4) Throw the two rubber balls on the floor and measure which bounces the higher.

5) Feel the two balls with one's hand see which is the firmer.

Correct responses: FISS 64%, SISS 71%, Difference 7%

[Example 2] Area: Earth Science, Objectives: Application

The following table shows temperatures at different times over a three-day period from Monday to Wednesday.

	6:00 am	9:00 am	12:00	3:00 pm	6:00 pm
Monday	15°C	17°C	20°C	21°C	19°C
Tuesday	15°C	15°C	15°C	10°C	9°C
Wednesday	8°C	10°C	14°C	14°C	13°C

Choosing from the following responses, at which time do you think a cold wind suddenly began to blow?

1) Monday morning

2) Monday afternoon

3) Tuesday morning

4) Tuesday afternoon

5) Wednesday morning

6) Wednesday afternoon

Correct response rate: FISS 64%, SISS 71%, Difference 7%

Now let us look at 2 examples where the responses on this SISS is lower than those on the previous FISS.

[Example 1] Area: Physics, Objectives: Understanding

The pulse rate and breathing rate for 1 minute was measured before and after running a 50 meter race. From the following responses, which is the correct one?

1) Pulse rate doesn't change, but breathing is slower

2) Pulse rate is faster, but breathing doesn't change

3) Pulse rate and breathing are faster

4) Pulse rate and breathing are slower

5) There is no change

Correct response rate: FISS 87%, SISS 75%, Difference 12%

[Example 2] Area: Earth Science, Objectives: Knowledge

How long will it take for a spaceship to travel from the earth to the moon? Choose from the following answers.

1) 2 hours

2) 5 or 6 hours

3) 2 or 3 days

4) 1 light year

5) 5 or 6 years

Correct response rate: FISS 75%, SISS 45%, Difference 30%

Table 13 shows differences between SISS and FISS by subject area, objectives and overall average correct response rates in respect of the lower secondary school population.

Table 13: A Comparison between the Present SISS and Previous FISS Survey - 3rd Year Lower Secondary School Population

Area/ Objectives	No. of Questions	Average Ratio SISS(a)	Average Ratio FISS(b)	Difference (a) - (b)
Physics	15	71.0%	66.9%	4.1%
Chemistry	6	56.4	47.1	9.3
Biology	10	64.8	60.6	4.2
Earth Science	2	64.3	83.5	-19.2
Knowledge	11	65.6	66.0	-0.4
Understanding	10	65.4	56.7	8.7
Application	12	67.1	63.9	3.2
Total	33	66.1	62.4	3.7

In terms of the lower secondary school population, from the point of view of average correct replies, one can say that the overall marks have improved. In terms of subject area, apart from earth science, the average correct response rate has improved for physics, chemistry and biology. In terms of objectives, average correct response rates have improved for 'understanding' and 'application'.

If one makes a comparison in terms of individual questions, one finds that out of 33 questions, there are 16 correct answers, about half, with a statistically significant higher correct response rate on this SISS than the previous FISS. On the other hand, there are only 7 where the response rate was significantly higher on the previous FISS than this SISS. If one simply compares questions where the difference in the correct response rate is 5% or more, one finds 14 questions where the correct response rate is higher on this occasion and 3 where it is lower. The overall average correct response rate is 66.1% on this occasion, compared to 62.4% on the previous occasion. One can therefore say that in respect of the secondary school population, the results in science have become better on this SISS than on the previous FISS.

Now let us look at 2 examples, where the problems have become substantially better this time.

[Example 1] Area: Chemistry, Objectives: Understanding

Assume 2 elements which, when combined, produce a poisonous compound. Given this fact, what can one say about the nature of these two elements? Choose from the following responses:

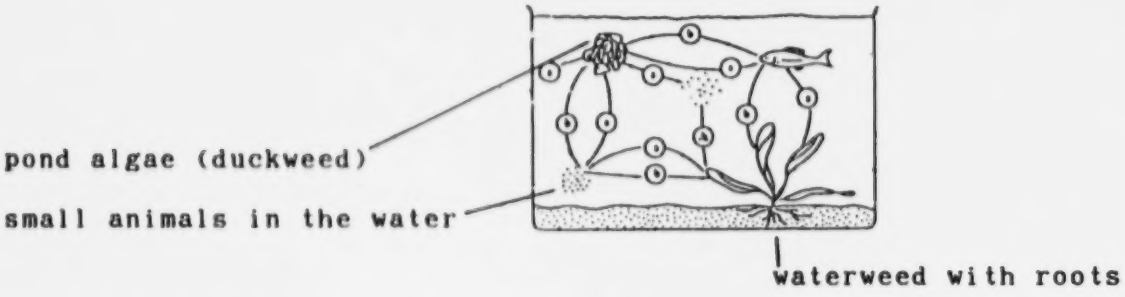
1) Both the 2 elements are undoubtedly poisonous.
2) At least 1 of the 2 elements is undoubtedly poisonous.
3) One of the elements is poisonous, but the other is not.
4) Neither element is poisonous.

5) Neither of the elements is necessarily poisonous.

Correct response rate: FISS 24%, SISS 55%, Difference 31%

[Example 2] Area: Biology, Objectives: Understanding

The following diagram shows the relationship between biological organisms living in water. What these organisms are taking in or ejecting is shown by a) and b) respectively.



From the following responses, choose the one where a) and b) are both correct:

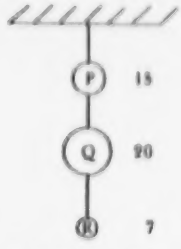
1)	a) = oxygen;	b) = carbon dioxide
2)	a) = oxygen;	b) = a carbohydrate
3)	a) = nitrogen;	b) = carbon dioxide
4)	a) = carbon dioxide;	b) = oxygen
5)	a) = carbon dioxide:	b) = a carbohydrate

Correct response rate: FISS 65%, SISS 80%, Difference 15%

Looking at cases where the problems on this SISS became substantially worse, there are 2 in the field of earth science and one in physics. Let us look at the physics problem as an example.

[Example] Area: Physics, Objectives: Application

As shown in the following diagram, 3 objects, P, Q and R are suspended from a single thread. The weights of P, Q and R are 15g, 20g and 7g respectively. What weight is pulling on the thread at a point between P and Q. Choose from the following responses:



1) 42g
2) 35g
3) 27g
4) 15g
5) 7g

Correct response rate: FISS 60%, SISS 51%, Difference 9%

5. Results from Other Points Investigated

On Practical Tests

Practical tests (process exercises) are given as an international option, and a small number of countries, including Japan, Hungary and Singapore carried these out.

For both the elementary school and lower secondary school populations, 2 sets of 3 problems each were compiled and divided between 2 groups of schools selected on a random basis.

Looking at the results, from the point of view of the degree of difficulty, the correct response rate for the 5th year elementary school students was 63.6%, while that for the 3rd year lower secondary school students was considerably lower at 47.7%.

Also, taking as yet unpublished data from Hungary and Singapore, if one looks at the results classified by objectives or aim, one finds that for simple skills such as observation, measurement or simple manipulation, Japan does not fall below the other countries, but in the case of higher level skills such as drawing a conclusion, formulating a hypothesis, carrying out inferential reasoning, etc. lower secondary school students in Japan are at a substantially lower level compared to the other tow countries.

Factors Affecting Points Gained in Science

Among the factors found to have a significant correlation with points gained by the students in science are:

For all populations : 'number of books in the home', 'attitudes (like/dislike) towards science'; and,

For 3rd year lower secondary and 3rd year upper secondary populations: 'plans (hopes) for future studies', 'study time outside school', 'study time on science outside school', etc.

Other factors with a fairly high correlation, leaving the 3rd year upper secondary school earth science sub-population aside, are: 'value judgment regarding science', 'attitudes (like/dislike) towards school', 'interest in science', 'attitudes towards a scientific job', etc. For both 5th year elementary school students and 3rd year lower secondary school students there is also a correlation with experiments carried out by students'.

Using multiple regression analysis, taking all the factors from students questionnaire, school questionnaire and teacher questionnaire, one finds that for 5th year elementary school students the factors that have a positive influence on variations in

points for common science problems include 'number of books in the home', 'experiments carried out by students', the budget per students', 'cultural activities by the PTA', 'the number of weeks of learning activities in a year', 'financial support from the PTA', 'self-evaluation of science results', 'attitude towards school', etc. For 3rd year lower secondary school students, the factors with a positive influence on variations in points for common science problems include 'plans for future studies', 'time spent on science study outside the school', 'percentage of science teachers in the school', 'number of books in the home', 'frequency of use of the science room', 'revision of lessons by the teacher', 'opportunity to learn science', 'financial help from the PTA', 'weight laid by the teacher on systematic understanding by the students', 'self-evaluation of science results', etc.

On Sex-based Trends in Attitudes Towards Science

If one investigates separately for boys and girls trends in attitudes towards science and other points, one finds that for 5th year elementary school students, boys have a much stronger interest in science than girls, while girls have a more favourable image of school. Also, if one investigates the connection between attitudes to science and points gained for common problems, one finds that for boys the correlation is highest for 'interest in science', followed by 'attitude (like or dislike) towards school' and 'value judgment of science', whereas for girls the correlation is highest, for 'attitude (like or dislike) towards school', followed by, 'interest in science' and 'value judgment of science'.

If one look at sex-based trends in attitudes towards science, etc. in respect of the third year lower secondary school population, one finds that, as in the case of elementary school students, boys have a stronger interest in science, also girls have a better image of school. A noticeable feature is also that boys have a more favourable image than girls of science-based jobs.

Moreover, if one looks at connections between attitudes to science and points gained in common science problems, one finds that for boys and girls 'interest in science' has the highest correlation, followed for boys, in order of decreasing correlation, by 'scientific attitude', 'value judgment of science', 'attitude (favourable/unfavourable) towards scientific job' and 'attitude (like/dislike) towards school', and for girls, in order to decreasing correlation, by 'scientific attitude', 'attitude (like/dislike) towards school', 'attitude (favourable/unfavourable) towards scientific job' and 'value judgment of science'.